*Volume 37* December, 1951 *Number 12*

# Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants



THIS ISSUE

Grease Lubrication at High Speeds

PUBLISHED BY
THE TEXAS COMPANY
TEXACO PETROLEUM PRODUCTS

# LUBRICATION

A TECHNICAL PUBLICATION DEVOTED TO THE SELECTION AND USE OF LUBRICANTS

Published by

The Texas Company, 135 East 42nd Street, New York 17, N. Y.



Vol. XXXVII December, 1951 No. 12

*Change of Address:* In reporting change of address kindly give both old and new addresses.



## Grease Lubrication at High Speeds

PROGRESS in industry, from the time of the Industrial Revolution when handwork was being replaced by power driven machinery, has been paralleled by an increase in the surface velocity or rotational speed of such machinery. This trend has been noteworthy during the past few decades as these increases in speed have accompanied increases in power output and production capacity.

Basically any over-all increase in machinery speed is related to increased speeds of bearings or gear assemblies. This calls for closer tolerances, precision fits of mating parts, and smooth polished bores or surfaces. These conditions which are so essential for high efficiency and sustained operations are obtained by high speed grinding and machining. The ultimate results of this trend towards higher speed have been an improvement in quality of products, and an increase in the quantity of output per machine.

With increased speed, lubrication requirements become more stringent. The design of a new apparatus demands a careful analysis to determine its own particular requirements. Factors such as rotational or surface speed, the operating temperature range, applied and types of loads, and method of lubrication or means of supplying the lubricant to the moving parts must be taken into consideration. Accessibility of certain of the machine parts, space requirements, and expected or desired lubricant life are other factors that dictate the type of lubricant (oil or grease) needed. All these factors should be considered by the designing engineer when the machine is in the drafting board stage. He can profit by consulting with a lubrication engineer who is familiar with the ultimate conditions under which the machine is to operate. The type of lubrication for such conditions should be determined at this stage of the design.

With the advent of rotational speeds above 10,000 r.p.m., oil was given first consideration due primarily to the diverse methods by which it can be applied. It is, however, subject to limitations. At slow speeds, a bearing, gear or other moving part can be lubricated by total immersion in the lubricant. At high speeds, however, the churning action developed in the lubricant produces a high frictional heat accompanied by a measurable loss in power. To avoid this churning action, the designer turned to methods which feed a measured amount of oil to the bearing. This is accomplished by oil rings and slingers, metering plugs, wick feeds, oil mist or drip feed. Oil circulating systems are employed to supply the lubricant to plain and anti-friction bearings, particularly where the latter are operating at high ambient temperatures and under severe loading conditions. A force-feed lubricating system requires a pressure feed pump and sometimes a scavenging pump to insure complete circulation of the oil. For the system to be completely effective, there must be no stagnation or settling of oil in so-called dead spots.

### HOW GREASE LUBRICATION IS APPLIED

The methods employed for lubricating with grease cover a wide range. The driving journals of a steam locomotive are lubricated by a cake of grease held in contact with the journal by a spring. Large steel mill rolling machines have centralized lubrica-

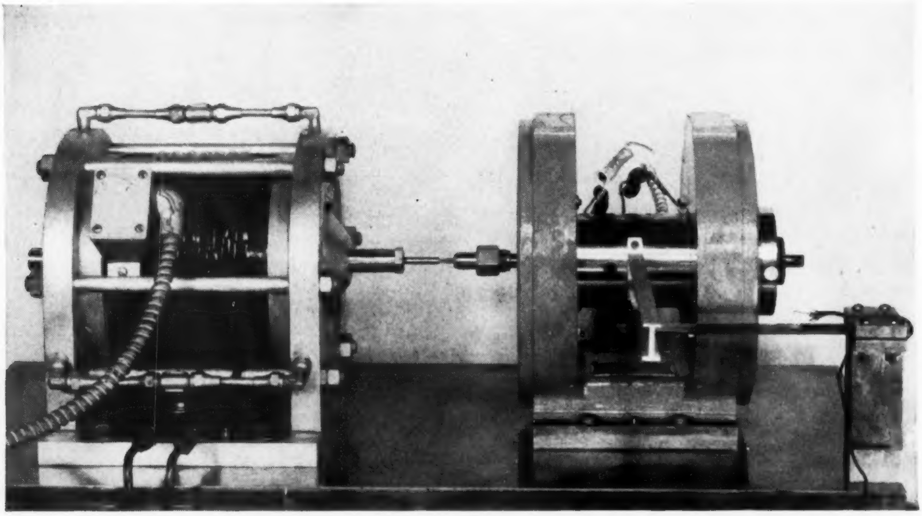

Figure 1 — Showing the 7 h.p., 36,000 r.p.m., 600 cycle motor mounted on the test stand base and connected to the grease test unit by a "necked-down" shaft and collet. The grease test unit rests on relatively friction-free rollers enclosed in the pedestals. The torque measuring system and electrical resistance strain gages are shown in the foreground while the thermocouple lead wires are directly above the test bearing housing.

tion systems, while other machines in industry have the familiar grease cup or fitting for lubrication with a hand or pressure grease gun. Grease is more dependable than oil for certain types of bearings located in inaccessible places, or where compactness is a desirable feature. It is practicable to provide bearings so designed and sealed that re-lubrication may only be necessary at very infrequent intervals.

## GREASE—A VERSATILE LUBRICANT

Grease, the versatile lubricant, aside from a few scattered applications, has not been too widely adopted for rotational speeds much above 10,000 r.p.m. Present day greases function with outstanding dependability under the conditions for which they are rightly specified. Certain types of greases are available for operation over an ambient temperature range from minus 100° F. to plus 250° F. and at speeds up to 10,000 r.p.m.; others will lubricate anti-friction bearings rotating at 10,000 r.p.m. at temperatures up to 300° F. for hundreds of hours. What then are the limitations imposed on greases at speeds above 10,000 r.p.m.? A survey of the field of grease lubrication yielded very little information. It did, however, clearly indicate that a fundamental study would be in order.

## THE TEST UNIT

Obviously a test unit is required which is suitable for the evaluation of grease lubrication at high speeds (see Fig. 1). A special type of electric motor capable of operating at speeds up to 36,000 r.p.m. is required as the drive. This motor is connected to the grease test machine by a "necked-down" shaft designed so as to rupture in case the grease test unit should seize or operate under high torque conditions induced by faulty lubrication.

### Drive Motor

The drive motor is a Westinghouse 220 volt, 600 cycle squirrel cage, water cooled induction motor rated 7 h.p. at 36,000 r.p.m. Two motor generator sets are used to convert the laboratory electrical supply of 60 to the required 600 cycles.

A 50 h.p. 60 cycle squirrel cage motor is directly coupled to a 250 volt DC generator. The voltage from the DC generator is used to operate a 30 h.p. DC motor in the second motor generator set. This 30 h.p. motor is directly connected to a 25 KVA high frequency generator which in turn supplies the power to operate the 7 h.p. 36,000 r.p.m. grease test apparatus drive motor. A 5KW 1750 r.p.m., 125 volt flat compound-excitor supplies the voltage to both generators. A tachometer generator, mounted on the shaft of the DC motor, actuates a tachometer voltmeter that is installed in the control panel board. The tachometer is calibrated in cycles per second and the actual speed is obtained by multiplying the tachometer voltmeter reading by sixty.

Figure 2 shows the auxiliaries necessary to operate the 36,000 r.p.m. motor. The rotor of the motor rests on two plain bearings which are lubricated by means of an oil circulating system. A circulating system of this type requires that the oil be fed to the bearings at a definite pressure and volume. The oil must also be scavenged from the bearings and returned to the sump for recirculation. Oil is fed to the bearings under a pressure of 15 p.s.i.g. and at a

rate of 0.8 gallons per minute. An automatic oil pressure controller will shut down the entire unit should a failure in the oil circulating system occur. The oil circulating system is shown in the foreground of Figure 2.

It is obvious that if grease would supply adequate lubrication of the test motor bearings at high speeds, the auxiliaries necessary for oil lubrication would be eliminated. This would effect a substantial savings in equipment, space and maintenance; three very important factors.

All switches required for operating the motor generator sets, auxiliaries and 36,000 r.p.m. motor are located on a central control panel. The temperatures of the inlet and outlet oil and water supplies are measured and automatically recorded.

## Grease Test Machine (see p. 144)

Figure 3 is a cross section drawing of the grease test machine showing the position of the test bearings, housing, cradle mount, loading device and "necked-down" shaft held in a collet. Also shown are the positions of thermocouples used to measure the bearing temperatures which are also automatically recorded. The spindle on which the test bearings are mounted is made of a high grade alloy steel. To relieve all stresses the spindle was heat treated after rough grinding. Diameters were held concentric within 0.0001 in. and after the machine work was completed, it was dynamically balanced.

The diameters are held to dimensions that allow a light press fit for the bearings. The ends of the shaft are threaded for right and left side slingers which function as lock-nuts to hold the inner races of the test bearings in position on the spindle. One end of the spindle is drilled and tapped for a left hand thread into which the shaft of an Erickson collet is screwed. In operation the collet clamps the "necked-down" drive shaft, the opposite end of which is screwed into the 36,000 r.p.m. motor shaft.

## Bearing Housing

The housing is made from a high grade alloy tool steel with all surfaces ground and polished after hardening, all dimensions being held to very close tolerances to provide precision fits of the mating parts. The outer race of one test bearing, (left as shown in Figure 3), is locked in position by the end cover plate. The test bearing on the opposite end of the spindle is lightly pressed into a sleeve which in turn fits into the housing with a slip fit, but does not shoulder against the housing. This arrangement provides for the application of a thrust load on the test bearings as explained on page 144.

The inner races of both bearings are locked firmly against shoulders on the spindle; the outer race of one bearing is locked in position in the housing by the end cover plate and annular ring. The outer race of the second bearing, however, is left free to float in the horizontal plane in order for a thrust load applied to the floating outer race to

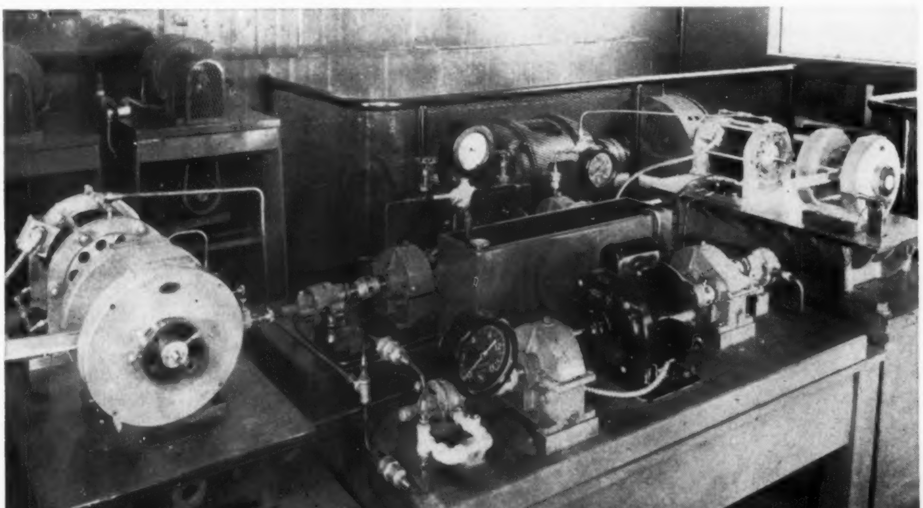

**Figure 2 — The auxiliary motors, reduction gears, oil pumps, lines and sump, required to provide lubrication for the 7 h.p., 36,000 r.p.m. drive motor bearings are seen in the center foreground. One of the two motor generator sets required to convert the laboratory electrical supply from 60 to 600 cycles is seen in the background.**

force the race against the balls. This load in turn is transmitted to the second test bearing by the spindle.

## Loading Mechanism

Load is applied by using nitrogen under pressure to expand a metallic bellows or diaphragm, as shown at the extreme right of Figure 3. This bellows is inserted between the outer cover plate and annular ring which butts against the outer race of the bearing. The pressure side of the bellows is connected through suitable reduttion and pressure control valves and tubing to a nitrogen cylinder. A thrust load beyond the load limit of the bearing can be applied by this means.

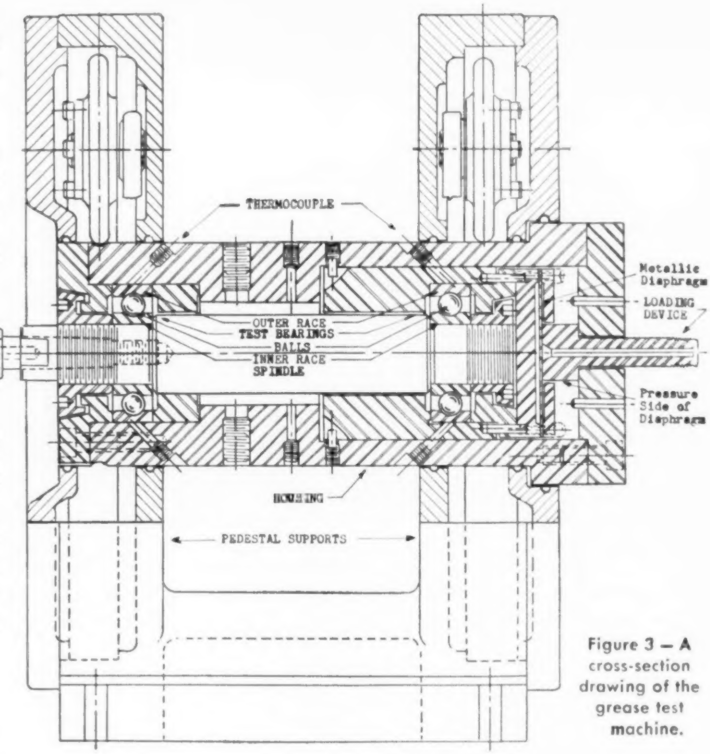


Figure 3 — A cross-section drawing of the grease test machine.

## Test Bearings

The ball bearings used for test purposes are the super precision Annular Bearing Engineering Committee No. 7 grade. These are mounted in duplex pairs either face to face or back to back.

## Housing Cradle and Torque Measuring System

The test bearing housing fits into a relatively friction free cradle, supported on each end in a pedestal. Two 0.25 in. wide, 2.5 in. diameter steel rollers with ball bearing centers are supported on studs attached to the pedestal wall to form the cradle. A third roller in each pedestal functions as a positioner and vibration dampener. These latter rollers can be lifted from or locked in position against the housing wall. A groove with 9/64 in. radius is ground into one end of the housing periphery. The rollers in one pedestal operate in this groove and prevent lateral play.

A light aluminum torque arm is mounted on the periphery of the bearing housing equidistant from each end of the housing. An adjustable weight is also mounted on the opposite side of the bearing housing to counterbalance the weight of the torque arm. A knife edge on the torque arm fits into a knife edge seat on the pressure measuring components. The pressure measuring component is made up as follows: a spring steel lever arm 10.25 inches long by 0.5 inches wide and 0.0625 inches thick is clamped on one end in a steel pedestal mounted on the motor base. A knife edge seat is fastened on the lever arm close to the top of the extended or free end. The lever arm is adjusted so that when the torque arm on the bearing housing is in a horizontal plane, the knife edge on the arm is aligned and in contact with the knife edge seat on the steel lever arm. Two $SR_4$* strain gages are mounted on the lever arm close to the support pedestal. The active gage is mounted on the top side of the lever arm and the temperature compensator is directly underneath the first. The strain gages are connected to a Foxboro strain recorder.

## Temperature Measurements

Pencil type iron-constantın thermocouples are inserted through holes provided in the bearing housing so that they butt against the periphery of the outer race of the test bearings. The bearing temperatures together with all other temperatures on the motor oil and water systems are automatically recorded.

## Evaluation of Greases

Two types of test procedures are considered desirable for evaluating greases on anti-friction bearings at high rotative speeds: (a) a relatively short time

*The trade name for the Baldwin Locomotive Company resistance wire strain measuring gage.

screening test that will rapidly eliminate those greases which are entirely unsuitable for lubricating bearings in the high speed range; (b) a longer endurance type test, to determine the lubricating qualities of those greases which appear satisfactory on the basis of the screening test.

The conditions established for the short time or screening test are thrust loads of 125 pounds, speeds of 10, 20, 30, and 35 thousand r.p.m. and test duration of 90 minutes. The endurance type test is operated at 35,000 r.p.m. under a thrust load of 80 pounds for eight periods of eight hours each.

The time period of 90 minutes for the screening test is set because in most cases bearing temperatures and torques reach a peak, decline and come to equilibrium within that time. For the endurance test a test period of 64 hours has been adopted due to limitations of time.

The basic ratings of ball bearings as established by bearing manufacturers are derived from a formula which includes speed, load and a life expectancy of a definite number of hours. The internal load in the bearing due to the force of the balls against the outer race is negligible at low speeds. At speeds above 5000 r.p.m., this force becomes a factor and must be subtracted from the basic load ratings to obtain the actual. These load ratings are checked experimentally by the bearing manufacturer with oil lubricated bearings.

The 125 pound thrust load used for the screening test, although only 62.5 per cent of the rated load capacity of the bearing at 35,000 r.p.m., produces a rapid test for separating the serviceable greases from the unserviceable. The 80 pound thrust load (40 per cent of bearing rated capacity at 35,000 r.p.m.) for the endurance test represents about twice that usually specified for most high speed applications.

The grease charge for both types of test is limited to 2.6 grams, the amount required to fill the free space in the bearing. The test bearings are unshielded and the design of the bearing housing provides a free space into which the grease could be thrown from the bearings. Any grease thrown into the free space is unavailable for lubrication. This method of lubricating the bearing further accelerates the tests as only the grease that adheres to the bearing in the vicinity of the balls and ball path can function as a lubricant. An AN-G-15a (all purpose aircraft) grease was selected for test purposes.

Data are presented in Figure 4 showing the effect of speed and thrust load on the operation of a grease lubricated bearing. As the efficiency of a lubricant is measured by its ability to reduce friction and thereby the generation of heat in the bearing, running temperature of the bearing provides a criterion of the lubrication supplied.

The curves are presented as a trend since only single determinations have so far been made at each speed and load. At speeds of 5 and 10 thousand r.p.m. the applied load has relatively little effect on the bearing running temperatures. At 30 and 35 thousand r.p.m. the effect of load becomes appreciable. The data shown in Figure 4 dictated the selection of test conditions used for the evaluation of greases.

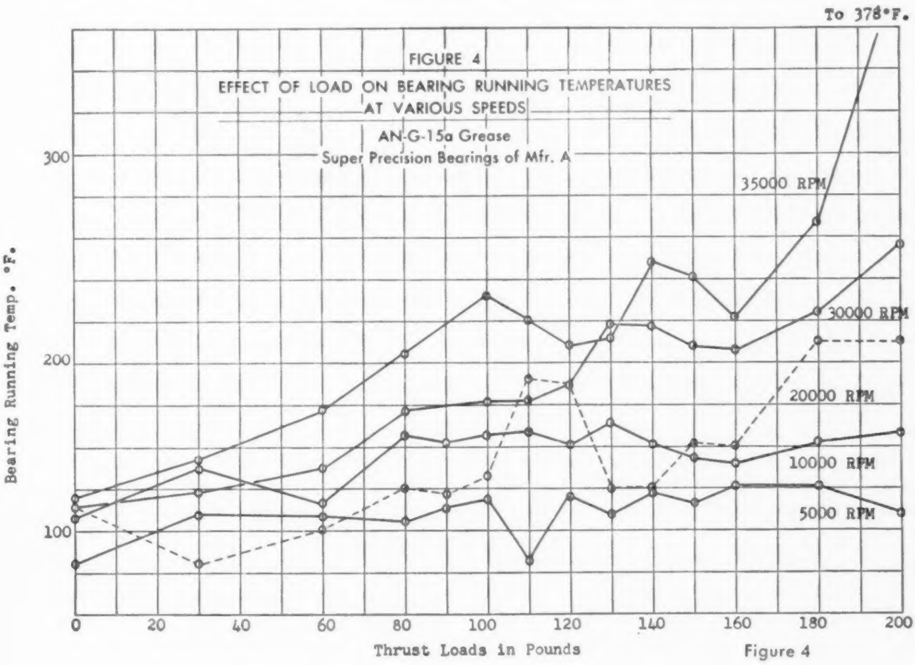

Figure 4

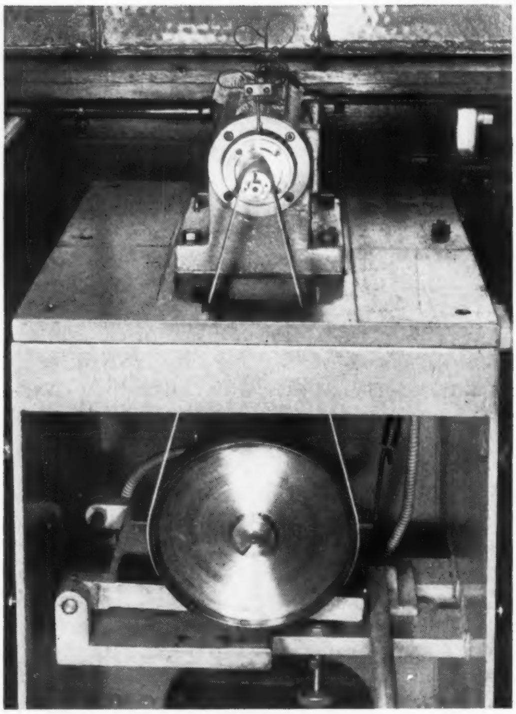

Figure 5 — A view of the 35,000 r.p.m. long time test assembly showing the drive motors connected to the grease test unit by a flat woven linen belt. A ten to one pulley ratio gives the desired speed. The thermocouples for measuring bearing temperatures are inserted in the bearing housing directly above the test bearings.

A number of different types of greases have been tested under the screening test conditions. Although the factors of bearing running temperature predominated, other factors such as amount and condition of grease on the bearing, distribution and leakage are used to judge the performance of a grease. The data are summarized and presented in Table I using bearings from manufacturer A, see Table III, page 148.

The shear susceptible sodium-calcium soap grease and the water stabilized calcium greases were not satisfactory for further evaluation due to operating above their melting point.

It is interesting to note that the anhydrous calcium soap grease supplies excellent lubrication, whereas the water stabilized type is a poor lubricant under the conditions of test.

The products which qualified under the screening test were then subjected to the endurance test. The data obtained are contained in Table II, page 148.

It might be well to digress at this point in order to bring out more clearly the versatility of grease as a lubricant. The AN-G-15a type grease meets government specifications for operation at —40° F.; at 250° F. it will satisfactorily lubricate an anti-friction bearing operating at 10,000 r.p.m. for over 500 hours and for 250 hours at 300° F. It will also provide excellent lubrication at 35,000 r.p.m. under a moderately heavy load. The AN-G-25a grease (made with a synthetic oil) will provide lubrication for a bearing operating at minus 67° F; it will also lubricate for over 1000 hours at 10,000 r.p.m. and 250° F. and although it failed to complete the 64 hours under the endurance test conditions, it would in all probability be satisfactory for lubrication at 35,000 r.p.m. under light loads over an extended period of time. The experimental AN-G-5a type grease made with a synthetic oil will when applied to a No. 204 ball bearing allow it to rotate one full revolution in five seconds at —40° F. with an applied torque of 2000 gram centimeters. Yet this grease will lubricate that same bearing for over 1600 hours at 10,000 r.p.m. and a bearing running temperature of 300° F. It will also continue to lubricate with the same degree of efficiency at 35,000 r.p.m.

The data presented in Table II justifies the assumption that grease can supply satisfactory lubrication for anti-friction bearings operating at rotative speeds up to 35,000 r.p.m.

## CORRELATION WITH SERVICE

To quote an old adage, "the proof of the pudding is the eating thereof", how do the data presented compare with service conditions? To ascertain the relationship between the laboratory tests and service conditions, another test apparatus was designed and is now in use. This, as shown in Figure 5, operates at 35,000 r.p.m. under a thrust load of 40 pounds for a period of 120 hours followed by a shut down of 48 hours. This time cycle simulates that of a production machine operating three shifts for a five day week. The AN-G-15a type grease satisfactorily lubricated the test bearings for a period of 2500 hours with bearing running temperatures 35 to 40° F. above ambient, conclusive proof that the endurance test conditions yield accurate data.

## EFFECT OF BEARING DESIGN AND MANUFACTURE ON GREASE LUBRICATION AT HIGH SPEEDS

Having obtained substantiating data on the effectiveness of grease as a lubricant for anti-friction bearings at rotative speeds up to 35,000 r.p.m., the next step indicated would be to determine the effect of bearing design. In general all bearings specified for high speed operation are the super precision types, made to meet the Annular Bearing Engineering Committee No. 7 grade requirements. All commercially available bearings of this grade have non-metallic ball retainers. Research on metallic ball re-

tainers made of various alloys and of non-conventional design is currently being promoted by the bearing manufacturers.

The super precision bearing with the non-metallic ball retainer, due to the retainer bulk, will permit a grease charge of only 2.5 to 3.0 grams whereas a bearing with a metallic retainer will take from 5.0 to 6.0 grams. In addition to its bulk, the non-metallic retainer does not readily lend itself to grease lubrication as the smooth surface provides no irregularities to which the grease can cling. As a result the grease is thrown off to the edge of the bearing outer race and is not readily available for lubrication.

Super precision bearings of ABEC No. 7 grade from four different manufacturers have been tested under the endurance test conditions to ascertain what effect design and manufacture have on grease lubrication in the 35,000 r.p.m. speed range. An AN-G-15a (all purpose aircraft lubricant) was used for the tests. The bearings all assembled with a non-metallic ball retainer differed somewhat in design of the ball retainer and the size and number of balls. A metallurgical analysis of the bearing metals and the composition of the non-metallic ball retainers is not known. The data obtained on the bearings are presented in Table III.

Three tests on bearings from manufacturer A resulted in the completion of two 64 hour tests, the third failing in 32 hours. The bearing running temperatures (used as the criterion of the lubrication supplied) developed by these bearings ranged between 230 and 341° F. with an overall average above 275° F. Bearings from manufacturer B completed two 64 hour tests with an overall average bearing running temperature somewhat below 200° F. Bearings from manufacturer C did not complete a single test. Failures occurred in 61.5, 4.75, and 23.5 hours. The D bearings also completed two full tests with one operating at an average bearing running temperature of 230° F. and the second somewhat above.

It is evident from the data that bearing design has a very decided effect on grease lubrication at high speeds. This is evidenced by comparing the performances of the bearings. Although all bearings were presumed to have been manufactured to

TABLE I – SCREENING TESTS

| *Grease* | *Bearing Running Temps., °F. at Speeds in Thousands r.p.m.* | | | | *Remarks* |
|---|---|---|---|---|---|
| | *10* | *20* | *30* | *35* | |
| AN-G-15a | 150 | 206 | 206 | 234 | Excellent lubrication |
| AN-G-15a type of NLGI No. 0 grade | 129 | 172 | 213 | 232 | Excellent lubrication |
| AN-G-15a type of NLGI No. 6 grade | 166 | 169 | 284 | 281 | Fair lubrication |
| AN-G-25a | 133 | 131 | 164 | 226 | Excellent lubrication |
| Mixed Sodium Calcium (Shear Susceptible) | 127 | 177 | 310 | 290 | Poor lubrication |
| Calcium Soap Water Stabilized NLGI No. 1 grade | 169 | 222 | 286 | 384 | Poor lubrication |
| Calcium Soap Water Stabilized NLGI No. 2 Grade | 213 | 232 | 266 | 288 | Poor lubrication |
| Calcium Soap Water Stabilized NLGI No. 3 grade | 300 | 220 | 236 | 259 | Poor lubrication |
| AN-G-5a Type Grease | 148 | 170 | 223 | 223 | Fair lubrication |
| Wide Temperature Range Grease | 146 | 178 | 239 | 256 | Good lubrication |
| Exp. AN-G-5a Type | 208 | 227 | 227 | 240 | Excellent lubrication |
| Anhydrous Calcium Soap Grease of NLGI No. 2 grade | 117 | 161 | 210 | 236 | Excellent lubrication |
| Exp. AN-G-5a Type Grease Synthetic Base | 117 | 267 | 252 | 272 | Good lubrication |

**TABLE II – ENDURANCE TEST**

*35,000 r.p.m., 80 Pounds Thrust Load, Eight 8 Hour Test Periods*

| Grease | Hours Run | Remarks |
|---|---|---|
| AN-G-15a | 64 | Excellent lubrication |
| AN-G-15a Type of NLGI No. 0 grade | 16 | Failed* |
| AN-G-15a Type of NLGI No. 6 grade | 7 | Failed* |
| AN-G-25 | 48 | Failed* |
| AN-G-5a | 24 | Failed* |
| Wide Temp. Range Grease | 64 | Good lubrication |
| Exp. AN-G-5a Type | 64 | Very good lubrication |
| Anhydrous Calcium Soap of NLGI No. 2 grade | 64 | Excellent lubrication |
| Exp. AN-G-5a Type Synthetic Base | 64 | Excellent lubrication |

*Indicated by bearing seizure.

the same degree of precision, (to meet grade 7 requirements) it will be noted from Table III that bearings from manufacturer C were unable to complete a single test. Of the remaining three makes, one had an average bearing running temperature below 200° F., the second around 250° F. and the third 275° F. The stress placed on bearing running temperatures stems from the fact that high temperatures have a deleterious effect on not only the grease, but also the non-metallic ball retainer. The non-metallic retainer when subjected to heat will tend to deform the ball pockets and if subjected to too high a temperature the surfaces will char.

To further confirm the data on bearing performance as related to grease lubrication at high speeds, a series of tests was made on greases that previously failed the endurance test. These tests were run on an AN-G-15a type grease of NLGI No. 0 grade using bearings from manufacturer B. Although this grease did not complete a single 64 hour test on bearings from manufacturer A, it came through with flying colors on the B bearings.

## CONCLUSION

The foregoing apparatus as designed for evaluating greases on anti-friction bearings, and the test procedures used have produced some very interesting data on grease lubrication at speeds up to 35,000 r.p.m. By use of this test apparatus and procedures it would seem to be possible to predict with a reasonable degree of accuracy, the expected performance of a grease in service installations. The knowledge that greases can be made to supply satisfactory lubrication at high rotative speeds opens a broader field for this type of lubrication.

Further study of grease lubrication of anti-friction bearings under even more severe test conditions should produce additional interesting data. It will be very desirable to have such data to prove or disprove the suitability of grease lubrication for bearings running as high as 100,000 r.p.m. at high ambient temperatures.

**TABLE III – ENDURANCE TEST ON BEARINGS OF DIFFERENT MANUFACTURERS**

*35,000 r.p.m., 80 Pounds Thrust Load, 8-8 Hour Periods* *AN-G-15a Grease as Lubricant*

| Ball Bearing Manufacturer | Bearing Running Temperatures, °F. at End of Each 8 Hour Period | | | | | | | | Grease Charge in g. | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|
| | 8 | 16 | 24 | 32 | 40 | 48 | 56 | 64 | | |
| A | 248 | 252 | 316 | 341 | 315 | 304 | 301 | 296 | 2.6 | Very high running temp. |
| | 248 | 249 | 255 | 276 | 319 | 276 | 277 | 275 | 2.6 | Both bearings rough |
| | 230 | 240 | 298 | 253 | 295 | | | | 2.6 | Failed in 32 hours One bearing seized |
| B | 203 | 197 | 185 | 190 | 187 | 190 | 185 | 191 | 3.0 | Very satisfactory performance |
| | 180 | 184 | 181 | 191 | 193 | 185 | 198 | 194 | 3.0 | Very satisfactory performance |
| | 218 | 192 | 191 | 196 | 191 | 190 | 195 | 211 | 3.0 | Failed in 61 hours One bearing seized |
| C | 245 | | | | | | | | 3.0 | Failed in 4 hours One bearing seized |
| | 346 | 304 | 310 | | | | | | 3.0 | Failed in 23.5 hours One bearing seized |
| D | 222 | 217 | 234 | 224 | 265 | 214 | 229 | 236 | 3.0 | Very satisfactory performance |
| | 238 | 235 | 255 | 259 | 269 | 271 | 282 | 250 | 3.0 | Higher operating temperatures Both bearings smooth |



Printed in U. S. A. by Salley & Collins, Inc. 305 East 45th Street New York 17, N. Y.

l

n-
d
o

n-
s,
y
n
le
is
n
h

u-
st
t-
to
o-
th
r-
ne
s-
a

on
ns
ill
is-
r-
gh

nce
nce

nce
ures

a. by
Inc
tree
. Y.

Good management boils down to this!

# Step up unit output

# keep down unit costs

**MANAGEMENT'S NO. 1** job is easy to describe, harder to achieve. But it is being done in every major field of industry and transportation with the assistance of skilled Texaco engineers plus superior Texaco quality lubricants.

**FOR EXAMPLE*** Engines in a mammoth Aluminum plant — one of the world's largest internal combustion plants — include 18 Nordberg Gas-Diesels which are lubricated with Texaco Ursa Oils exclusively. And this has been found to be true —

*Regardless of engine size, efficiency goes up and fuel consumption goes down when you lubricate with Texaco Ursa Oils.*

**THE TOUGH JOBS GO TO TEXACO!** Here's one instance — *More stationary Diesel h. p. in the U. S. is lubricated with Texaco Ursa Oils than with any other brand.*

**ONE PURCHASE AGREEMENT** puts this cost-cutting plan in action for all your plants, wherever located. Call the nearest Texaco Distributing Plant, or write The Texas Company, 135 East 42nd Street, New York 17, N. Y.

*Name on request


**TEXACO** INDUSTRIAL LUBRICANTS

**THE TEXAS COMPANY • TEXACO PRODUCTS • DIVISION OFFICES**

ATLANTA 1, GA., 860 W. Peachtree St., N.W.
BOSTON 17, MASS. . . . . . 20 Providence Street
BUFFALO 3, N. Y. . . . . . . . 14 Lafayette Square
BUTTE, MONT. . . . . . . . 220 North Alaska Street
CHICAGO 4, ILL. . . . . 332 So. Michigan Avenue
DALLAS 2, TEX. . . . . . . . 311 South Akard Street
DENVER 1, COLO. . . . . . . . . . . . 910 16th Street
HOUSTON 1, TEX. . . . . . 720 San Jacinto Street
INDIANAPOLIS 1, IND., 3521 E. Michigan Street
LOS ANGELES 15, CAL. . . . 929 South Broadway
MINNEAPOLIS 3, MINN. . . . 1730 Clifton Place
NEW ORLEANS 6, LA. . . . 919 St. Charles Street
NEW YORK 17, N. Y. . . . . 205 East 42nd Street
NORFOLK 1, VA. . . . Olney Rd. & Granby Street
SEATTLE 11, WASH. . . . . . . 1511 Third Avenue

Texaco Petroleum Products are manufactured and distributed in Canada by McColl-Frontenac Oil Company Limited.